

EGNOS System Test Bed: Achievements and Ongoing Upgrades

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BIOGRAPHY

Andrés Cruz received his Master degree in Electrical Engineering from the University of Zaragoza. He joined GMV's GNSS unit in 1998.

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José María Legido received his Master degree in Telecommunications Engineering from the Barcelona Polytechnical University. He joined GMV in 1993 and has been working since then in different GNSS related projects.

Dr. José Caro received his Ph.D. in Physics at Granada University in 1996. He has been working at GMV's GNSS unit since 1998.

Hugues Secretan joined the CNES (the French Space Agency) in 1983 after being graduated as engineer in electrical and mechanical. He has worked in the ESA GNSS-1 Project Office since 1998 as the ESTB manager. From 1995 to 1998, he was the CNES EURIDIS Project Manager. From 1987 to 1994, he was in charge of the positioning phases of geostationary satellites (orbital and attitude maneuvers on transfer orbits) in the CNES Flight Dynamic Center at Toulouse.

Norbert Suard is an Engineering Specialist in the CNES Ground Segment Development Division where he has over 15 years of experience in development and studies of navigation system augmentation (CE-GPS, EURIDIS, EGNOS-ESTB).

ABSTRACT

The EGNOS System Test Bed (ESTB) has been developed as a main tool for supporting EGNOS (European Geostationary Navigation Overlay Service) design and demonstration to users. After a successful design and development process, the ESTB has become operational in January 2000 and a MOPS [1] compliant Signal-In-Space (SIS) is today available through INMARSAT AOR-E providing a first continuous GPS augmentation service within Europe.

In parallel, other initiatives led by the European Space Agency (ESA) and the European Commission (EC) are being carried out to analyze the capabilities to expand the EGNOS service out of Europe. Areas of specific interest for that service expansion are Africa, South-America, India and Russia. In order to demonstrate the EGNOS expansion capabilities, the ESTB is currently being upgraded to implement the required modifications.

This paper will present the current ESTB performance as the basis for the experimentation being carried out in support to EGNOS design. In particular, achieved performance in terms of accuracy, availability and integrity will be shown. Very promising results have been achieved considering the number of currently available Ranging and Integrity Monitoring Stations (RIMS).

In addition, the paper will also present the concepts and required design modifications in support to service expansion as well as the infrastructure being developed for investigating the performance in the expanded area. Some considerations related to potential SARPS/MOPS modification to improve the service expansion capabilities will be also discussed.

Keywords: EGNOS, EGNOS System Test Bed (ESTB), Service Expansion, Performance.

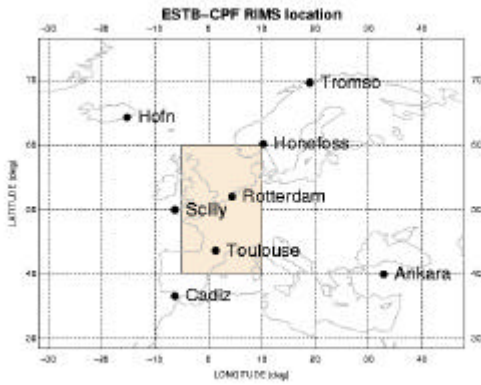


Figure 2: ESTB-CPF RIMS location and Service Area

3. FUNCTIONAL DESCRIPTION

The real time chain for the WAD/Ranging data generation and message production is depicted in Figure 3.

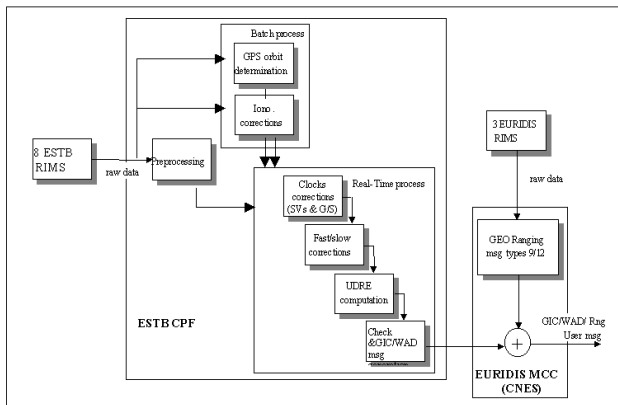


Figure 3: ESTB-CPF Architecture

The functions implemented in the ESTB CPF are those required for the generation of EGNOS WAD messages. These functions provide WAD corrections to GPS (corrections to GLONASS are not provided). They are not further described as they conform to well-known SBAS (Satellite-Based Augmentation Systems) architectures.

Functions related to GEO are included in the EURIDIS MCC (Master Control Center). Algorithms and performances of the GEO ranging are described in [6], [7] and [8].

4. ESTB OPERATIONAL MODES AND ASSOCIATED SIGNAL-IN-SPACE

Different ESTB modes of operation have been defined, each one implementing a different set of functions [5]

The different types of broadcast messages according to ESTB mode are summarized in Table 1. Content and usage of each type of message are described in Ref. [1].

Table 1: Messages broadcast according to ESTB mode

ESTB mode	Types of broadcast messages	Availability through	
		AOR-E	IOR
internal test	0 or 63	Yes (0)	Yes (63)
only ranging	1, 9, 12, 17, 24, 63, (0)*	Yes	No
clock only corrections	0, 1, 2, 3, 4, 7, 25**, (63)**	Yes	Yes
clock corrections & ranging	0, 1, 2, 3, 4, 7, 9, 12, 25**, (63)**	Yes	No****
No orbit corrections	0, 1, 2, 3, 4, 7, 9, 12, 18, 25**, 26, (63)**	Yes	No****
No orbit corrections & no ranging	0, 1, 2, 3, 4, 7, 18, 25**, 26, (63)**	Yes	Yes
GIC/WAD corrections	0, 1, 2, 3, 4, 7, 18, 25, 26, (63)**	Yes	Yes
GIC/WAD corrections & ranging	0, 1, 2, 3, 4, 7, 9, 12, 18, 25, 26, (63)**	Yes	No****

* depending on internal MCC status, not often used

** depending on unavailability of ESTB message at the NLES for the current epoch, not often used, just in case of network disturbances concerning links CPF/MCC or MCC/NLES.

*** fields *slow correction* filled with 0, except clock.

**** in case of reception of ranging messages through IOR, they will be filled with 0 and the slot for PRN 131 in message type 1 will be set to 0.

5. CURRENT PERFORMANCE

5.1. General

ESTB-CPF implements today a set of processing algorithms that were developed back in 1998. Since then, algorithms design has been largely improved in the frame of the operational EGNOS development, by taking benefit of the experience gained during ESTB development and the performance analyses obtained along the ESTB exploitation. In spite of those algorithmic improvements, the analyses of the current ESTB capabilities still provides a very good basis for getting major confidence in EGNOS design and performance budget consolidation.

Three scenarios have been executed to analyze the performance results:

1. Correction messages provided by GMV's implementation on ESTB-CPF, fed with stored data from 7 ESTB RIMS (dated May 7th, 2000, from 01h00m till 23h59m). User performance for a static receiver located at Toulouse (France) are computed by means of ESTB-PET (Performance Evaluation Tools). No use is made of the GEO ranging capability.
2. Based on actual SIS provided by the operational ESTB, processing data from the 8 ESTB RIMS on

September 1st 2000. User data are handled by a real static user located at Toulouse.

- Based on actual SIS provided by the operational ESTB, processing the 8 ESTB RIMS on September 1st 2000, from 12h00m till 15h00m. User performances are computed for a real static user located at Toulouse (Pegasus' tool figure, courtesy of EUROCONTROL [4]) taking advantage of the GEO ranging capability.

The short duration of the considered scenarios does not allow an exhaustive performance analysis and, hence, results have to be understood only as *indicators* of the provided performance.

It must be underscored that for all scenarios the number of RIMS is quite reduced. This obviously strongly constraints the performance especially in what concerns ionosphere and UDRE (User Differential Range Error) computation. It is also interesting to point out that the two users referred in the description of scenarios 2 and 3 utilize receivers from two different manufacturers.

Performance analyses are presented at three levels:

- CPF functional performance concentrated on UDRE and GIVE (Grid Ionospheric Vertical Error) computation functions performance.
- Overall Service performances that are attained from two independent receivers and ESTB-PET.
- GEO Ranging (as provided by EURIDIS) time determination.

5.2. CPF Functions Performance

Among the different CPF functions, UDRE and GIVE computation deserves special attention as it directly drives the overall service performance.

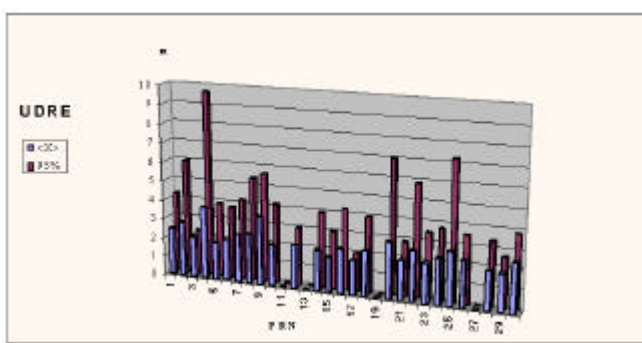


Figure 4: UDRE. Mean and 95 percentile (1st scen., 23 hours duration)

UDRE. The performance of the User Differential Range Error computation function has been analyzed. Figure 4 displays the mean and 95th percentile of UDRE for all GPS satellites as computed in 1st scenario.

It is worthwhile mentioning that satellite PRN 5 was monitored part of the time by only 2 RIMS (namely Toulouse and Cadiz) because of the breakdown of RIMS at Scilly; this accounts for the higher satellite UDRE values.

GIVE.

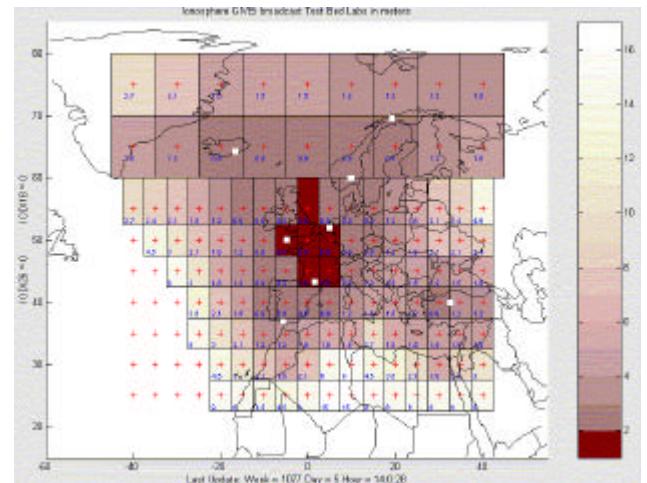


Figure 5 shows a map with the GIVE obtained in the 2nd scenario. This figure, when considering the RIMS location, evidences the high dependence of the quality of the ionospheric delay determination on the RIMS geometry. Indeed, the broadcast GIVE for the IGP's (Ionospheric Grid Points) in the center of the ESTB service area is much lower than the one for the surroundings. This is the expected behavior, because a higher number of IPPs (Ionospheric Pierce Points) around an IGP increases the available statistics in GIVD (Grid Ionospheric Vertical Delay) determination resulting in lower errors in the estimation and hence lower GIVE values.

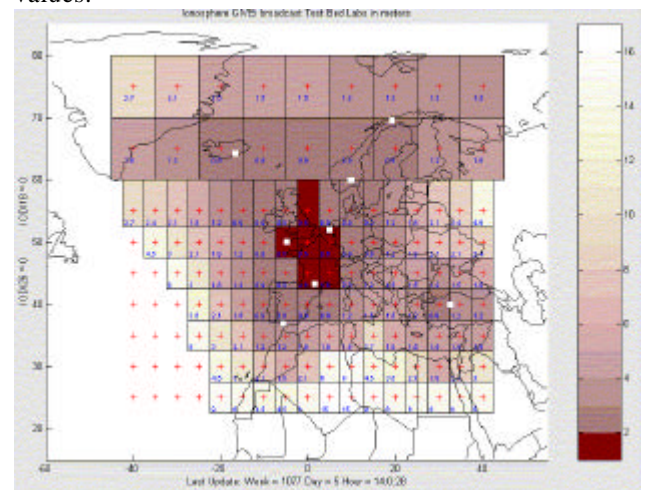


Figure 5: GIVE estimates (2nd scen. 14h00m28s)

5.3. Overall Service Performance

Overall service performance are measured at user level paying special attention to vertical performance, as corresponding requirements are the most stringent ones. Performance analyses are based on the evaluation of Vertical Position Errors (VPE) measured as the difference

between navigation solution and actual position, and Vertical Protection Levels (VPL) computed for the Precision Approach (PA) flight phase [1].

Note that, in addition to the reduced amount of data used for the study, the fact that performance is analyzed for a particular fixed location (not for the worst user in the service area) implies that extrapolation of the results to overall service performance is not straightforward.

VPL and VPE evolution and statistics

Analysis of VPL and VPE as a function of time and associated statistics provides a good insight into the service performance at user level.

The Figure 6 shows the VPL and VPE evolution for a static user (1st scenario). Peaks in VPL correspond to epochs of bad satellite geometry.

The VPL ripple (that contributes in more than a meter to the VPL computation) is mainly associated to the application of the degradation parameters described in Ref. [1]. It is magnified to display the link between broadcast WAD correction message type and computed PL.

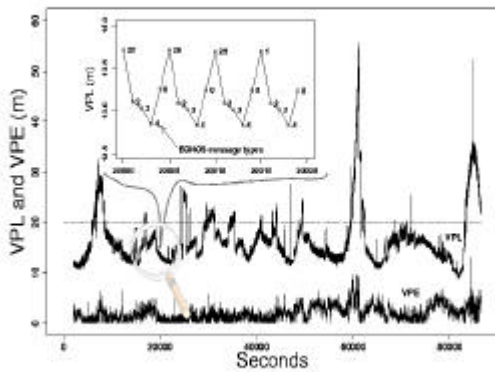


Figure 6: VPL and VPE vs. time (1st scen., 23 hours)

VPE distribution is represented for 1st scenario in Figure 7 where the histogram of the errors is shown together with the associated statistics values (mean, std. deviation and 95th percentile).

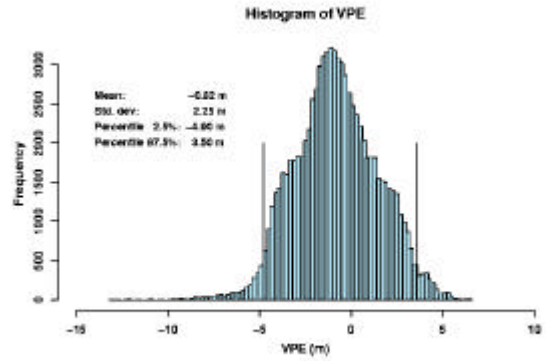


Figure 7: VPE histogram (1st scen., 23 hours duration)

Table 2 summarizes those statistic values for both vertical and horizontal errors.

Table 2: Navigation statistics (1st scenario)

	Average	Std. Deviation	95%
VPE (m)	-0.82	2.25	4.45
HPE (m)	1.41	0.73	2.86

It should be noted that, taking into account the correlation period of VPE (its autocorrelation function yields an autocorrelation time of approximately 40 minutes), the number of uncorrelated samples turns out to be relatively low. In this context it is not surprising to find an average vertical position error close to 1m.

The Figure 8 depicts the xPL evolution for a static user (3rd scenario, 3 hours duration, ESTB-CPF using 8 RIMS). No integrity failure was observed during the investigated period. The Position Error obtained is summarized in the Table 3.

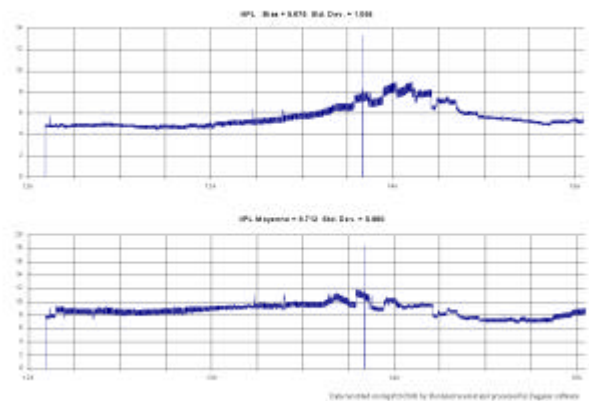


Figure 8: HPL and VPL (3rd scen., 3 hours duration). Courtesy of EUROCONTROL.

It is remarkable that the availability results associated to this scenario are much better than that of 1st scenario. Although there is not enough statistics to conclude that this result is systematic, this could be explained by the following facts:

- there is one more RIMS in 3rd scenario, namely Scilly;
- the user seems to be in a better location with regard to the ESTB RIMS distribution;
- 3rd scenario benefits by the AOR-E GEO ranging capability.

Table 3: Navigation statistics (3rd scen.)

	Average	Std. Deviation
VPE (m)	-0.55	1.40
HPE (m)	1.41	0.80

VPL/VDOP and VPE/VDOP Analysis:

VPL and VPE are directly affected by both ESTB-CPF performance and satellite geometry (measured by the VDOP -Vertical Dilution of Precision- parameter). In order to partially decouple both effects and provide a better insight into the ESTB performance, the analysis of VPE/VDOP and VPL/VDOP can be very helpful.

The Figure 9 shows the ratio of VPL to VDOP. The range of this parameter measures the efficiency of the ESTB to provide the required service availability. On the other hand, its degree of stability shows the capability for the performance predictability.

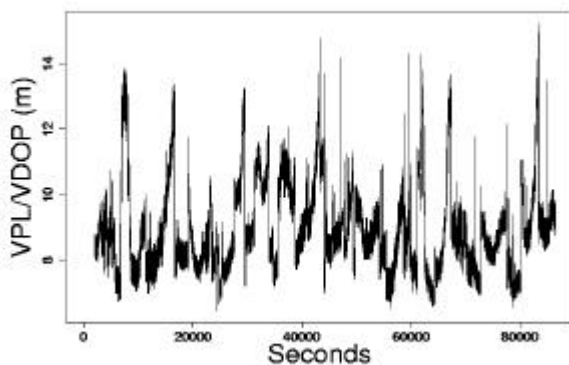


Figure 9: VPL/VDOP vs. time (1st scen.)

Further analysis is being currently performed to better understand the variations of this ratio, which is influenced by RIMS geometry, error dependence with satellite elevation, time for filters to converge, etc.

The ratio of VPE to VDOP provides an indicator of UERE (User Equivalent Range Error) after the application of WAD corrections and hence of the expected achievable accuracy performance.

Figure 10 shows the histogram of VPE/VDOP parameter for the 1st scenario. A mean value of -0.44m with a standard deviation of 1.26 m have been computed.

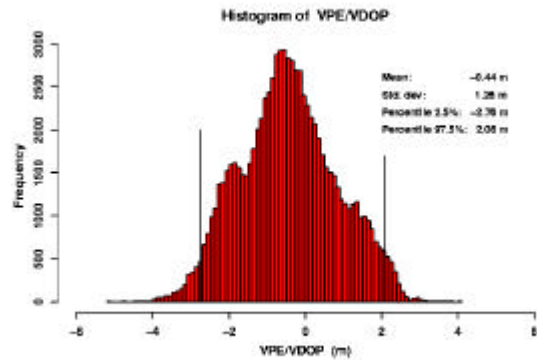


Figure 10: VPE/VDOP histogram (1st scen.)

VPL maps

Due to major effect of the user location in the corresponding performance, geographical analyses are also important.

Figure 11 displays the VPL obtained for 1st scenario at 13h00m. Values below 15 meters are attained within the complete ESTB service area identified in Figure 2. It is clear in the contour shapes of the figure what the impact of the RIMS location in VPL performance is. The time evolution of this map showed changes with periods of a few tens of minutes. Occasionally the VPL exceeded the 20 meter level all over the depicted area.

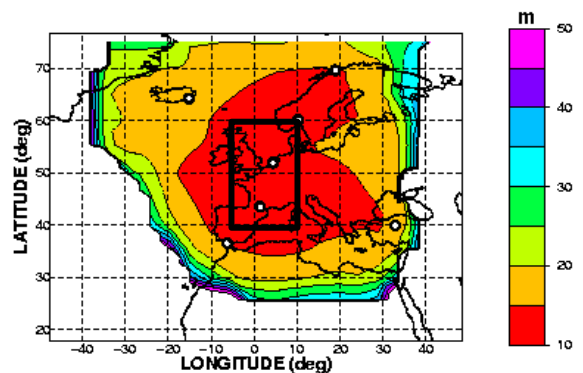


Figure 11: VPL contour map over Europe (1st scen.)

VPL vs. VPE: Availability vs. Integrity.

Integrity and Availability performance are very well represented using the diagrams introduced by the Stanford University where VPE (in horizontal) and VPL (in vertical) pairs as computed every epoch are plotted. Epochs of service availability (where VPL is smaller than the Vertical Alert Limit) and service integrity (where VPE is smaller than VPL) are easily identified.

Figure 12 shows the results attained in 1st scenario. The color code represents the density of points in each particular zone. Integrity is ensured in a 100% of the cases. Availability of 85.7% is measured for an Alert Limit of 20 meters.

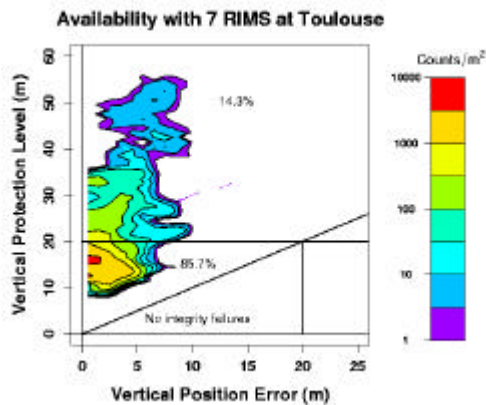


Figure 12: VPL vs. VPE (1st scen. 23 hours duration)

The resulting availability for different Alert Limits is depicted in Figure 13 for a user at Toulouse (cf. 1st scenario). For instance, for NPV-II (VAL=20m), achieved availability reached the already mentioned 85.7% while for NPV-I service (VAL=50m) the achieved availability is very close to 100%.

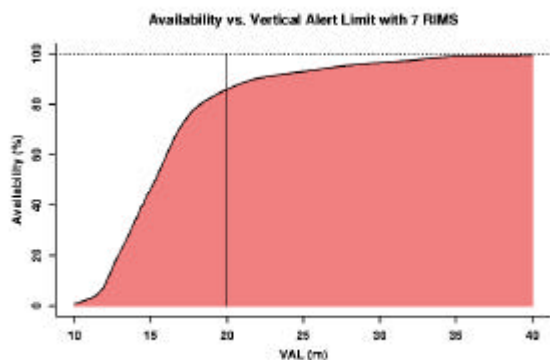


Figure 13: Availability vs. VAL (1st scen.)

5.4. Time Determination with message type 9

This section presents some results obtained in time restitution when using ESTB messages type 9 by comparison with time restitution when using GPS navigation messages [9].

The clock used as reference (REF) is a HP Caesium clock, type 5071 located at Aussaguel (France).

The GPS/GEO time determination using only ESTB message type 9 is made according to the following algorithm:

- Determination of REF-GEO_{SV15mn} data by :
 - Corrections on each one-second pseudorange
 - ✓ geometric delay between ground antenna and broadcast ephemeris from messages type 9
 - ✓ ionosphere delay from dual frequency measurements towards GPS and extrapolated in direction of the GEO (nearest GPS method)
 - ✓ troposphere delay from a P,T,H model
 - ✓ Sagnac correction
 - ✓ Geo clock corrections from broadcast ephemeris (message type9)
 - ✓ antenna and local clock cable delay
 - A least square linear fit over each 15 minutes data set
- Filtering over 24h of REF-GEO_{SV15mn} data, arc shifting every two hours, to obtain GPS/GEO time model.

The GPS time determination using all-in-view GPS satellites is made by the EURIDIS Algorithm already tested by comparison with BIPM algorithm [7]. The main steps of this algorithm are:

- Determination of each REF-GPS_{SV15mn} with broadcast ephemeris and dual frequency measurements for the computation of the ionosphere delays
- Determination of REF-GPS_{15mn} data by an average of REF-GPS_{SV15mn} obtained for each in-view GPS satellite
- Filtering over 24h of REF-GPS_{15mn} data, arc shifting every two hours, to obtain GPS time model.

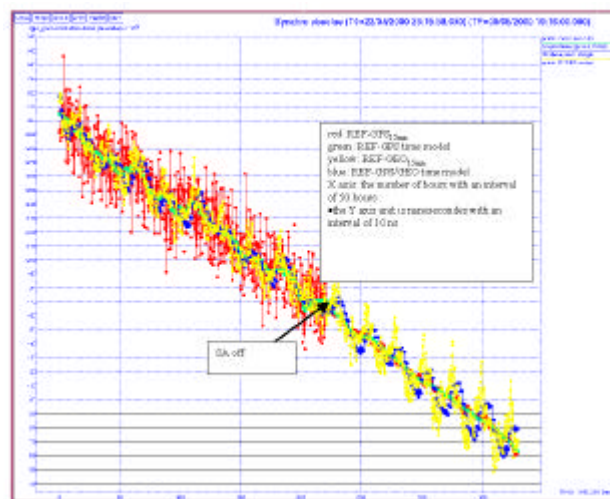


Figure 14: Comparisons from 22 April till 8 May, 2000

It is clear that before the GPS SA (Selective Availability) was switched off, the quality of the time determined with ESTB messages 9 was equivalent or better than time determined with GPS message navigation.

Currently, it is no longer the case (time determined with GPS without SA has a better accuracy and no improvement has been made on EURIDIS ground segment to increase the quality of Ranging messages). Now, accuracy when using ESTB messages is mainly limited by the quality of the GEO ephemeris determination and its extrapolation over 12 hours.

6. ONGOING DEVELOPMENTS

ESTB will be upgraded by the end of October 2000. The new release will include the necessary changes in order to broadcast SIS in compliance with the updated MOPS [2]. Besides, an additional enhanced navigation service (*Expanded Service Capability*) out of ESTB service area will be made available. This section is focused on the latter, starting with a description of expansion concept and major issues affecting EGNOS design.

6.1. Expansion Concept and Objectives

While EGNOS is designed to provide an enhanced navigation service over its service area, other users still within the coverage area of the GEO satellite(s) providing the EGNOS service could potentially benefit from EGNOS. This leads to the concept of Expansion Service that is aimed at providing a controlled service out of the nominal service area. Different concepts and architectures have been investigated depending on the relative location of the secondary service area and EGNOS primary service area [10]. Our analysis is focused on the provision of the service in remote areas (such as South America), since expansion to ECAC adjacent “small” areas (e.g. North Africa, Near East) can be implemented by simply enlarging the primary EGNOS service area.

Figure 16 shows the nominal EGNOS service area (ECAC), the footprint of the GEO satellites and typical extended and remote areas.

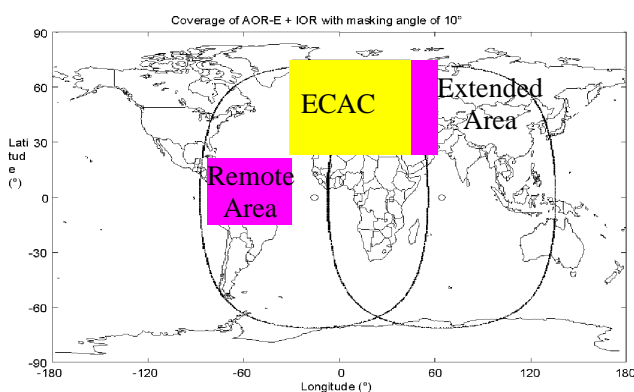


Figure 15: ECAC area and EGNOS GEOs footprint (Artemis satellite not included)

The service expansion, as compared to the implementation of a second regional system, allows an optimal

exploitation of EGNOS resources and especially of the GEO navigation transponder.

Performance objectives for areas not adjacent to the ECAC correspond to NPV-I [3] (VAL=50m), without impairing current service (in terms of Accuracy, Integrity and Availability) over EGNOS primary service area. Driving factor for the service expansion is the achievable VPL performance.

6.2. Major issues for Expansion Service

As a first step for the analysis of service expansion, a set of design drivers has been identified and analyzed. EGNOS design features that limit the expansion are firstly identified.

Progressive degradation of EGNOS service availability. With the baseline SBAS design, service performance is progressively degraded with the distance to the nominal service area, given by the fact that:

- Due to the lack of RIMS, the number of monitored GPS satellites and IGP progressively decreases with the distance to the nominal service area.
- GPS satellite corrections and associated boundings as broadcast by SBAS are not useful outside nominal service area. This particularly affects UDRE, which is solely computed for users within the nominal service area (proper bounding of errors out of this area is not warranted).

While addition of more RIMS in the expanded area could compensate the first limitation, the second implies modifications in the CPF design and, potentially, in SIS and user terminals. These changes, as necessary for the service expansion, are further analyzed.

Optimization of GEO bandwidth usage. Taking into account that the GEO message bandwidth is limited, the provision of further service in the expanded area requiring in particular the broadcast of additional ionospheric corrections and GIVE messages for the new IGPs in that area will imply that the “effective bandwidth” available for the nominal area is reduced.

In order for the service in the nominal area not to be affected, a minimum bandwidth needs to be reserved whose value has to be carefully analyzed as a function of different issues such as the expected worst ionosphere behavior. However, the suppression of SA provides additional margins that consolidate the feasibility of the service expansion.

In any case, service expansion has to be based on the use of a “limited bandwidth” which limits the service expansion size and/or the level of granularity of the IGPs. The latter is further constrained by the target performance (NPV-I): current analyses show that, under certain assumptions, such performances are reachable with a less

dense ionospheric grid (e.g. $10^{\circ} \times 10^{\circ}$). However, the applicability of this concept needs further investigation of the ionospheric activity in each target expansion area, specially considering the anomalous behavior in the equatorial zones.

Size of the Expansion Service area. With all above considerations, one can conclude that service expansion is feasible provided that an appropriate expansion area size is selected. The size of the expansion area shall be selected, mostly depending on the ionospheric activity in the expansion area. The defined expansion service can be provided over areas as large as ECAC and, under some assumptions, it could cover continental masses such as Africa and South America.

Reuse of CPF. One CPF, as currently designed, is sufficient to provide WAD corrections and integrity to both areas simultaneously. However, some important design modifications are required.

In particular, the current processing of the grid ionospheric vertical delay has been developed and verified for typical mid and high latitude ionospheric conditions. In contrast, regions to be monitored in the expansion area could belong to the ionospheric equatorial crest region, a zone of enhanced electron density at both sides of the geomagnetic equator (low latitude). Thus, the ESTB-CPF ionospheric computation design needs to be properly upgraded.

Integrity in the Expansion Service area. Users located in the expansion service area may be using GPS satellites also in view by users located in the primary service area. In order to guarantee integrity over the expansion service area, it is then necessary to degrade UDRE while maintaining the values in the nominal service area. Since message type 27 allows doing this, the definition of the expansion service area is achieved through the use of such a message. For the sub-areas identified in this message, a particular UDRE increment common to all satellites can be defined, thus ensuring integrity over the expansion service area. The definition of an appropriate “UDRE increment” that ensures the integrity while not unnecessarily decreasing the service availability is one of the key issues for the service expansion.

6.3. Infrastructure and target areas

In the case of EGNOS, and ESTB in particular, potential expansion areas are those under coverage of the AOR-E and IOR Inmarsat GBA (Geostationary Broadcasting Area), i.e. Central/South America continent (land mass and Caribbean islands), Africa continent (landmass), Near-East, Indian region and Russia. Different initiatives promoted by EC and ESA are being performed to expand the service in those areas. In particular, provision of service in South America is planned in 2001.

In addition to the mentioned CPF modifications, the following infrastructure has been developed to provide service expansion and analyze the provided performance:

- Additional RIMS for the expansion service require the following characteristics:
 - Portability. The RIMS design has been slightly changed in order to allow for an easy transportation and installation.
 - Autonomous communication means. In order to avoid any dependency from local communication means, each RIMS is equipped with a VSAT (Very Small Aperture Terminal).
- User Monitoring Unit. Consisting of one receiver compatible with ESTB SIS plus some SW tools that support the specific implementation of message type 27 in ESTB-CPF (explained in the following paragraph). These tools are also intended for the performance analysis of collected data.

6.4. Deviations from MOPS [2]

A major design driver has been to keep deviations with respect to current standards to a minimum. Nevertheless, some discrepancies were brought about by the *Expanded Service Capability* and the usage of message type 27 [2]. (Expansion ESTB-SIS will only slightly differ from MOPS standard. Moreover, differences will be only applicable for receivers to be used within expansion area.)

- Type 27 message will broadcast *ESTB UDRE Increment Indicators*, but it will not broadcast *ESTB Service Indications* to specify the class of service provided in the designated regions.
- Type 27 message will not be broadcast to reduce the level of service in a region (either within ESTB primary or secondary service areas), even in case of alarm condition due to onset of a reduced service level.
- Only one type 27 message with up to 7 regions will be broadcast.
- The *ESTB UDRE Increment Indicator* will be the same for all regions included in message type 27. Moreover, such a value will be a configuration parameter.
- ESTB users within the designated region will translate the broadcast *ESTB UDRE Increment Indicator* to *ESTB UDRE Increment Factor* by means of a table different from the table A-20 of Ref. [2].
- ESTB users within the designated region will multiply the *ESTB UDRE increment factor* with the received UDREs for all satellites.
- ESTB users will translate the broadcast *ESTB Region Radius Indicator* to degrees by means of a table different from the table A-21 of Ref. [2].

6.5. Preliminary Results on Expansion

Five additional RIMS (as a bare minimum) will be deployed and linked to the ESTB-CPF. The Expansion RIMS locations will be selected to provide an optimum coverage of the area to be monitored (remarkably for Iono and UDRE computation). Figure 16 depicts an example of configuration for Secondary Area. Simulations performed by GMV [10] show that NPV-I is reachable with availability better than 95%. It is to be noted that prior to the provision of the service to the expansion area, some previous experimentation is needed in order to better model the ionospheric behavior in each expansion area of interest.

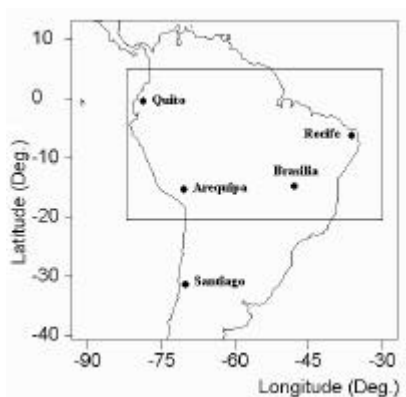


Figure 16: Example of expansion area

7. CONCLUSIONS

The already operational ESTB is a key tool for the EGNOS development and serves as backbone for R&D activities and demonstration to potential users. In particular, ESTB provides:

- A major tool for supporting EGNOS design in areas such as algorithms development, performance budget consolidation, etc.
- Support for investigating interoperability and expansion capabilities and their potential implications in the standardization process (e.g. improvement of message 27 definition).
- Capability to demonstrate different user applications allowing getting confidence in the service capabilities time in advance EGNOS becomes operational. Multimodal trials have been already planned, involving land, maritime, and rail users. In particular, flight trials were already performed by NATS/DERA with very satisfactory results. In the very near future, aviation community plans the systematic use of ESTB to analyze different operational flight procedures.
- Real time ionosphere observability that will help to better understand ionospheric behavior. This has obvious scientific value and can be also used as input to the EGNOS validation.

ESTB current performance analysis as presented along the paper provides promising results giving very good expectations on the future EGNOS capabilities. In particular, total absence of HMI (Hazardous Misleading Information) during all experiments, while obviously not demonstrating integrity requirements, gives major confidence in the design. Important accuracy and availability improvements (derived from algorithms optimization, new RIMS design and substantial improvement of RIMS number and location) are expected.

EGNOS service expansion has been outlined identifying the key elements for the provision of a warranted service out of ECAC area. Initial results anticipate the feasibility to provide NPV-I in remote areas while not disturbing the performance in the nominal service area. Infrastructure has been developed to provide service expansion. Demonstration in South America and, potentially other areas, is planned in 2001.

We expect the ESTB to further support the acceptance of EGNOS (and other SBAS) inside and outside Europe, eventually leading towards seamless (integrated) Global Navigation Satellite System (GNSS).

ACKNOWLEDGEMENTS

The authors would like to thank EUROCONTROL for its permission to include PEGASUS' tool figure.

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